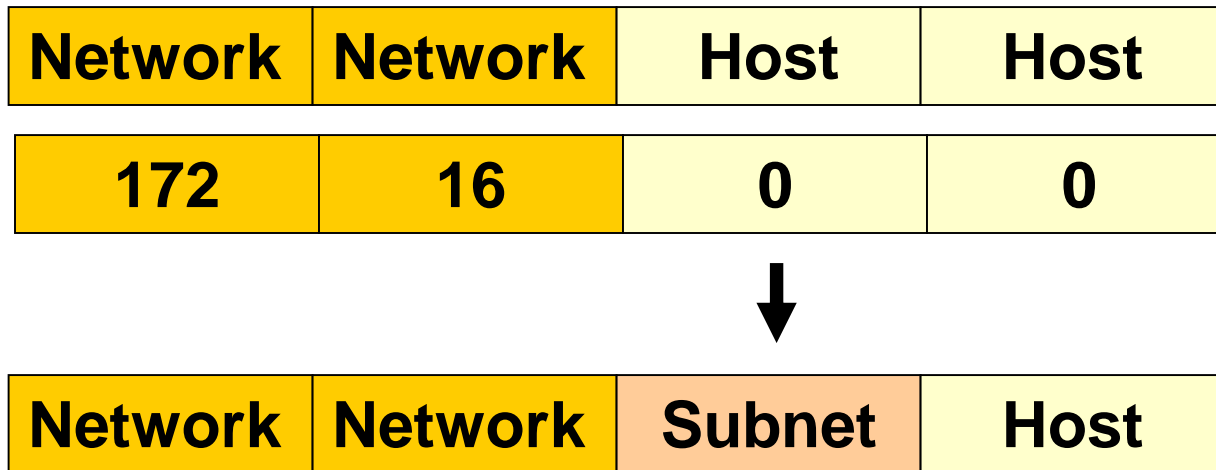


# Subnetting

## Week 7

Module : Computer Networks  
Lecturer: Lucy White [lbwhite@wit.ie](mailto:lbwhite@wit.ie)  
Office : 324

# What is subnetting?



- Subnetting is the process of borrowing bits from the HOST bits, in order to divide the larger network into small subnets.
- Subnetting does **NOT** give you more hosts, but actually costs you hosts.
- You lose two host IP Addresses for each subnet, one for the subnet IP address and one for the subnet broadcast IP address.
- In older technology, you would have lost the first subnet and last subnet, as in the first subnet the subnet IP address is the same as the network IP address. (This subnet can be used in most networks.) And in the last subnet and all of its hosts' IP addresses as the broadcast for that subnet is the same as the broadcast for the network.

# Reasons for Subnetting

Large networks need to be segmented into smaller sub-networks, creating smaller groups of devices and services in order to:

- Control traffic by containing broadcast traffic within subnetwork
- Reduce overall network traffic and improve network performance

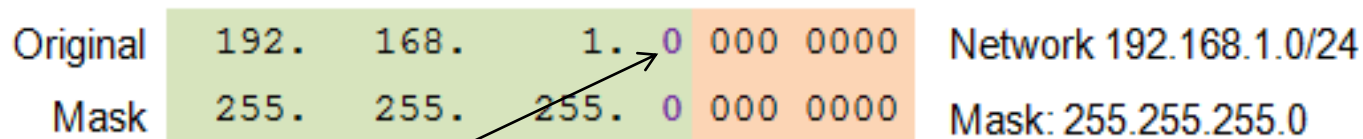
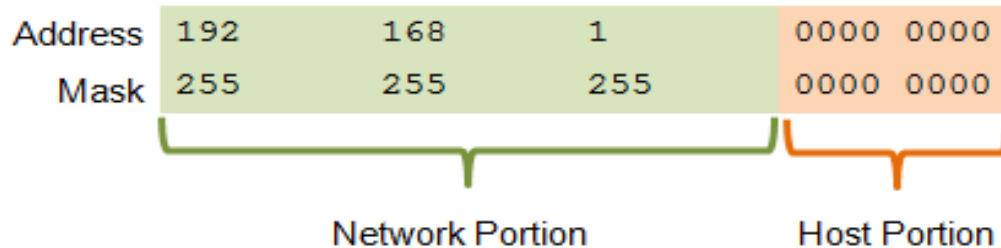
## **Communication Between Subnets**

- A router is necessary for devices on different networks and subnets to communicate.
- Each router interface must have an IPv4 host address that belongs to the network or subnet that the router interface is connected to.
- Devices on a network and subnet use the router interface attached to their LAN as their default gateway.

# Subnetting an IPv4 Network

## Basic Subnetting

- Borrowing Bits to Create Subnets
- Borrowing 1 bit  $2^1 = 2$  subnets



**Borrowing 1 Bit from the host portion creates 2 subnets with the same subnet mask**

### Subnet 0

Network 192.168.1.0-127/25

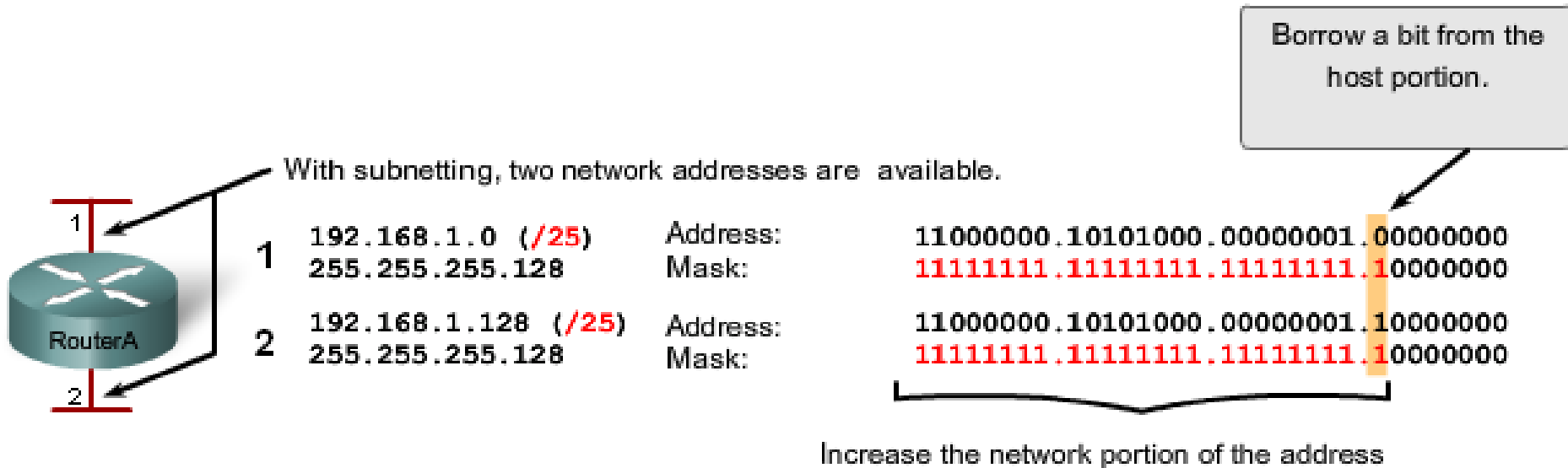
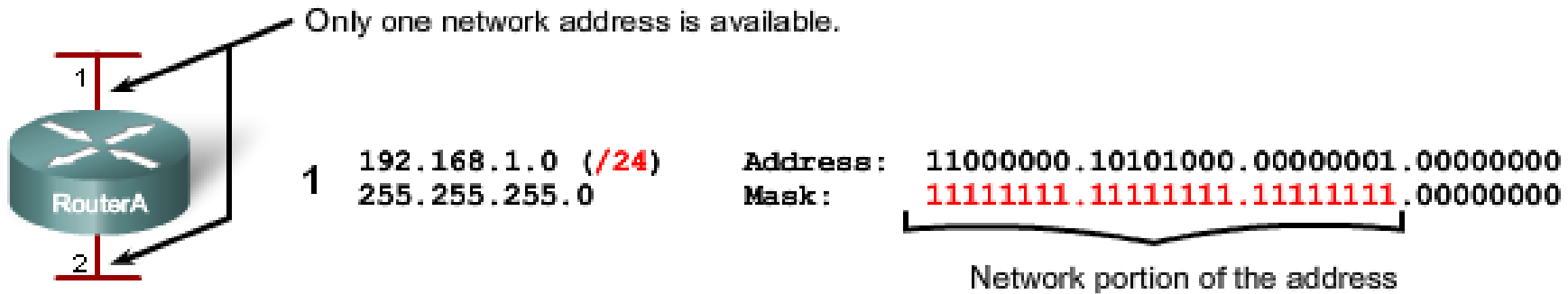
Mask: 255.255.255.128

### Subnet 1

Network 192.168.1.128-255/25

Mask: 255.255.255.128

## Borrowing Bits for Subnets



### Addressing Scheme: Example of 2 networks

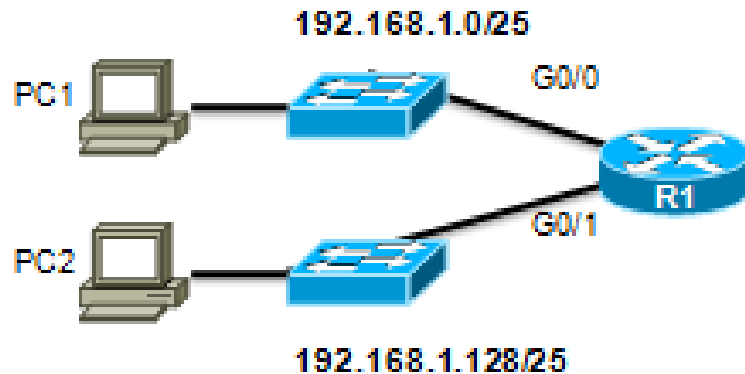
Subnet	Network address	Host range	Broadcast address
0	192.168.1.0/25	192.168.1.1 - 192.168.1.126	192.168.1.127
1	192.168.1.128/25	192.168.1.129 - 192.168.1.254	192.168.1.255

# Subnetting an IPv4 Network

## Subnets in Use

### Subnet 0

Network 192.168.1.0-127/25



### Subnet 1

Network 192.168.1.128-255/25

Address Range for 192.168.1.0/25 Subnet

Network Address

192. 168. 1. 0 000 0000 = 192.168.1.0

First Host Address

192. 168. 1. 0 000 0001 = 192.168.1.1

Last Host Address

192. 168. 1. 0 111 1110 = 192.168.1.126

Broadcast Address

192. 168. 1. 0 111 1111 = 192.168.1.127

Address Range for 192.168.1.128/25 Subnet

Network Address

192. 168. 1. 1 000 0000 = 192.168.1.128

First Host Address

192. 168. 1. 1 000 0001 = 192.168.1.129

Last Host Address

192. 168. 1. 1 111 1110 = 192.168.1.254

Broadcast Address

192. 168. 1. 1 111 1111 = 192.168.1.255

## Subnetting an IPv4 Network

# Subnetting Formulas

- Calculate Number of Subnets

Subnets =  $2^n$   
(where n = bits borrowed)

192. 168. 1. 0 000 0000



1 bit was borrowed

$2^1 = 2$  subnets

- Calculate N

Hosts =  $2^n$   
(where n = host bits remaining)

192. 168. 1. 0 000 0000



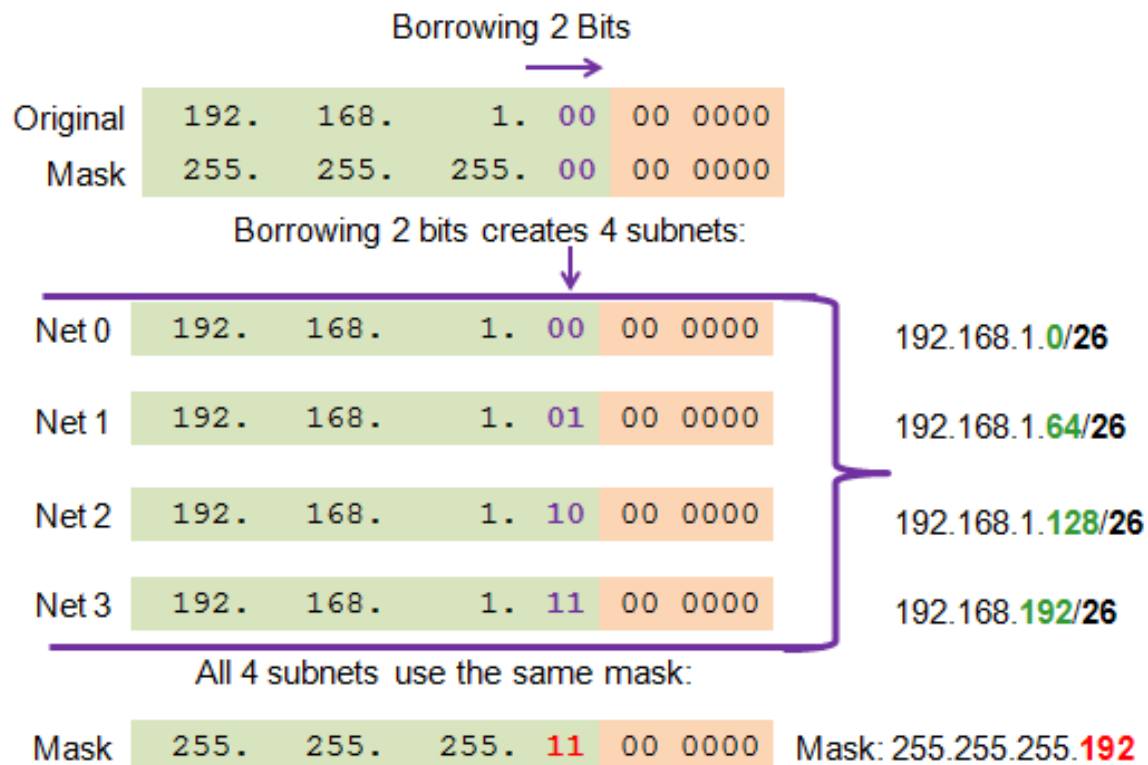
7 bits remain in host field

$2^7 = 128$  hosts per subnet

## Subnetting an IPv4 Network

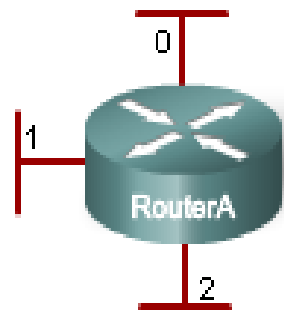
# Creating 4 Subnets

- Borrowing 2 bits to create 4 subnets.  $2^2 = 4$  subnets





## Borrowing Bits for Subnets



-	192.168.1.0 (/24) 255.255.255.0	Address: 11000000.10101000.00000001.00000000 Mask: 11111111.11111111.11111111.00000000
0	192.168.1.0 (/26) 255.255.255.192	Address: 11000000.10101000.00000001.00000000 Mask: 11111111.11111111.11111111.11000000
1	192.168.1.64 (/26) 255.255.255.192	Address: 11000000.10101000.00000001.01000000 Mask: 11111111.11111111.11111111.11000000
2	192.168.1.128 (/26) 255.255.255.192	Address: 11000000.10101000.00000001.10000000 Mask: 11111111.11111111.11111111.11000000
3	192.168.1.192 (/26) 255.255.255.192	Address: 11000000.10101000.00000001.11000000 Mask: 11111111.11111111.11111111.11000000

Two bits are borrowed to provide four subnets.

Unused address in this example.

A 1 in these positions in the mask means that these values are part of the network address.

More subnets are available, but fewer addresses are available per subnet.

## Subnetting an IPv4 Network

# Creating 8 Subnets

- Borrowing 3 bits to Create 8 Subnets.  $2^3 = 8$  subnets

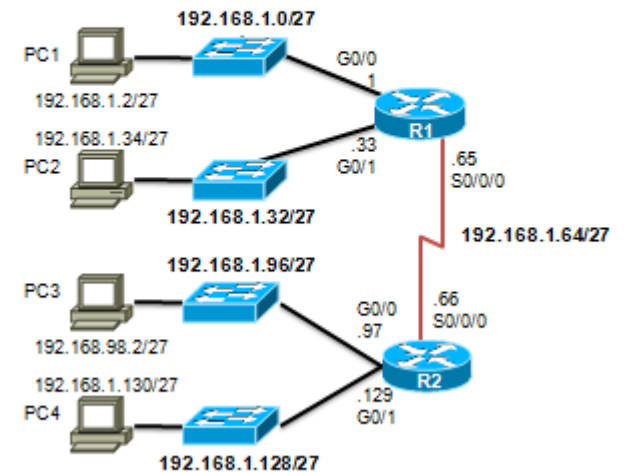
Net 0	Network	192.	168.	1.	000	0 0000	192.168.1.1
	Fist	192.	168.	1.	000	0 0001	192.168.1.1
	Last	192.	168.	1.	000	1 1110	192.168.1.30
	Broadcast	192.	168.	1.	000	1 1111	192.168.1.31
Net 1	Network	192.	168.	1.	001	0 0000	192.168.1.32
	Fist	192.	168.	1.	001	0 0001	192.168.1.33
	Last	192.	168.	1.	001	1 1110	192.168.1.62
	Broadcast	192.	168.	1.	001	1 1111	192.168.1.63
Net 2	Network	192.	168.	1.	010	0 0000	192.168.1.64
	Fist	192.	168.	1.	010	0 0001	192.168.1.65
	Last	192.	168.	1.	010	1 1110	192.168.1.94
	Broadcast	192.	168.	1.	010	1 1111	192.168.1.95
Net 3	Network	192.	168.	1.	010	0 0000	192.168.1.96
	Fist	192.	168.	1.	010	0 0001	192.168.1.97
	Last	192.	168.	1.	010	1 1110	192.168.1.126
	Broadcast	192.	168.	1.	010	1 1111	192.168.1.127

# Subnetting an IPv4 Network

## Creating 8 Subnets(continued)

Net 4	Network	192.	168.	1.	100	0	0000	192.168.1.128
	Fist	192.	168.	1.	100	0	0001	192.168.1.129
	Last	192.	168.	1.	100	1	1110	192.168.1.158
	Broadcast	192.	168.	1.	100	1	1111	192.168.1.159
Net 5	Network	192.	168.	1.	101	0	0000	192.168.1.160
	Fist	192.	168.	1.	101	0	0001	192.168.1.161
	Last	192.	168.	1.	101	1	1110	192.168.1.190
	Broadcast	192.	168.	1.	101	1	1111	192.168.1.191
Net 6	Network	192.	168.	1.	110	0	0000	192.168.1.192
	Fist	192.	168.	1.	110	0	0001	192.168.1.193
	Last	192.	168.	1.	110	1	1110	192.168.1.222
	Broadcast	192.	168.	1.	110	1	1111	192.168.1.223
Net 7	Network	192.	168.	1.	111	0	0000	192.168.1.224
	Fist	192.	168.	1.	111	0	0001	192.168.1.225
	Last	192.	168.	1.	111	1	1110	192.168.1.254
	Broadcast	192.	168.	1.	111	1	1111	192.168.1.255

**Subnet Allocation**



# Subnetting Based on Host Requirements

**There are two considerations when planning subnets:**

- Number of Subnets required
- Number of Host addresses required
- Formula to determine number of useable hosts
  - $2^{n-2}$
  - $2^n$  (where n is the number the number of host bits remaining) is used to calculate the number of hosts
  - $-2$  Subnetwork ID and broadcast address cannot be used on each subnet

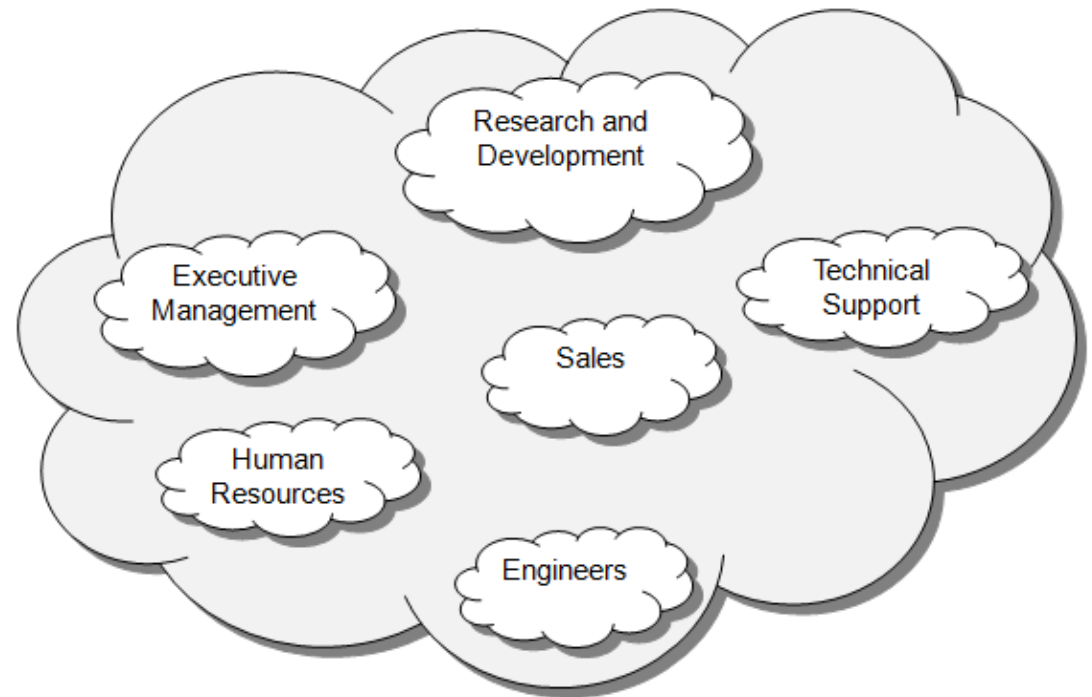
## Determining the Subnet Mask

# Subnetting Network-Based Requirements

Calculate number of subnets

● Formula  $2^n$  (where  $n$  is the number of bits borrowed)

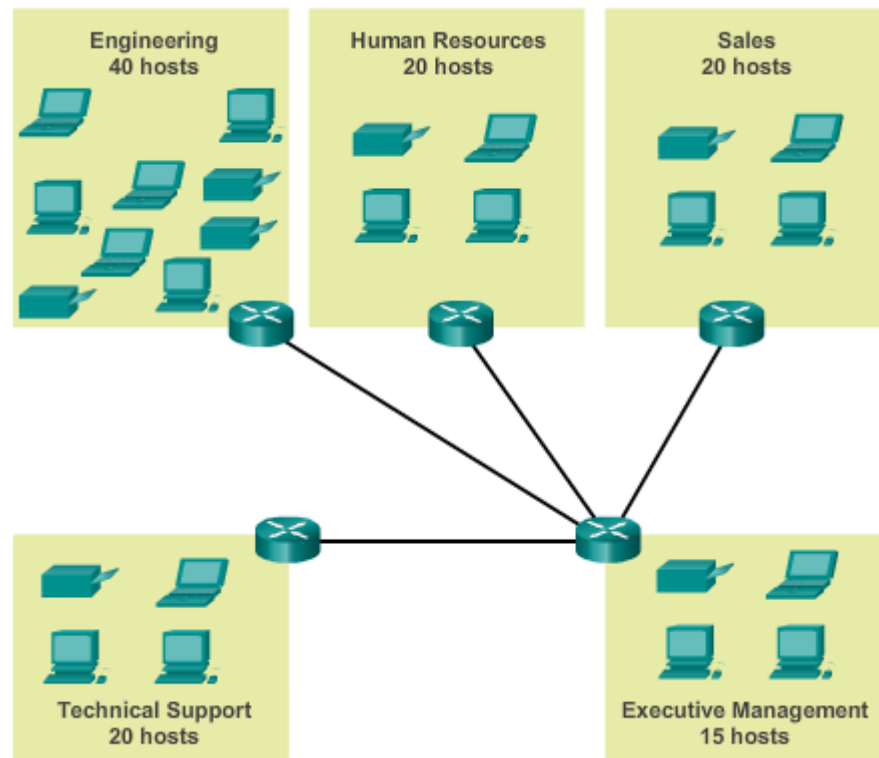
▪ Subnet needed for each department in graphic



## Determining the Subnet Mask

# Subnetting To Meet Network Requirements

- It is important to balance the number of subnets needed and the number of hosts required for the largest subnet.
- Design the addressing scheme to accommodate the maximum number of hosts for each subnet.
- Allow for growth in each subnet.



## Determining the Subnet Mask

# Subnetting To Meet Network Requirements (cont)

### Subnets and Addresses

	10101100.00010000.00000000.00.00000000	172.16.0.0/22
0	10101100.00010000.00000000.00.00000000	172.16.0.0/26
1	10101100.00010000.00000000.00.01000000	172.16.0.64/26
2	10101100.00010000.00000000.00.10000000	172.16.0.128/26
3	10101100.00010000.00000000.00.11000000	172.16.0.192/26
4	10101100.00010000.00000000.01.00000000	172.16.1.0/26
5	10101100.00010000.00000000.01.01000000	172.16.1.64/26
6	10101100.00010000.00000000.01.10000000	172.16.1.128/26

Nets 7 – 14 not shown

15	10101100.00010000.00000000.11.10000000	172.16.3.128/26
16	10101100.00010000.00000000.11.11000000	172.16.3.192/26

↗  
 $2^4 = 16$   
subnets

↖  
 $2^6 - 2 = 62$   
Hosts per  
subnet

# Subnet Example

Network address **172.16.0.0** with **/16 Base Network Mask**  
Using Subnets: **Subnet Mask 255.255.255.0** or **/24**

Subnet addresses: All 0's in host portion

Network	Network	Subnet	Host
172	16	0	0
172	16	1	0
172	16	2	0
172	16	3	0
172	16	Etc.	0
172	16	254	0
172	16	255	0

**Subnets  
Addresses**

**256  
Subnets**

**$2^8$**



# Subnet Example

Network address **172.16.0.0** with **/16** Base Network Mask

Using Subnets: **Subnet Mask 255.255.255.0** or **/24**

Network	Network	Subnet	Hosts		Broadcast	
172	16	0	1	→	254	255
172	16	1	1	→	254	255
172	16	2	1	→	254	255
172	16	3	1	→	254	255
172	16	Etc.	1	→	254	255
172	16	254	1	→	254	255
172	16	255	1	→	254	255

Each subnet has 254 hosts,  $2^8 - 2$

Host IP Address: 172.16.3.50

- A host of the 172.16.3.0 /24 network

**With NO subnetting:**

<u>Network</u>	<u>First Host</u>	<u>Last Host</u>	<u>Broadcast</u>
172.16.0.0	172.16.0.1	172.16.255.254	172.16.255.255

- 65,534 host addresses, one for network address and one for broadcast address.

Host IP Address: 172.16.3.50

- A host of the 172.16.0.0 /16 network

Host IP Address: 172.16.3.50

With subnetting:

- A host of the 172.16.3.0 /24 network

<u>Network</u>	<u>First Host</u>	<u>Last Host</u>	<u>Broadcast</u>
172.16.0.0	172.16.0.1	172.16.0.254	172.16.0.255
172.16.1.0	172.16.1.1	172.16.1.254	172.16.1.255
172.16.2.0	172.16.2.1	172.16.2.254	172.16.2.255
172.16.3.0	172.16.3.1	172.16.3.254	172.16.3.255
172.16.4.0	172.16.4.1	172.16.4.254	172.16.4.255
172.16.5.0	172.16.5.1	172.16.5.254	172.16.5.255
172.16.6.0	172.16.6.1	172.16.6.254	172.16.6.255
172.16.7.0	172.16.7.1	172.16.7.254	172.16.7.255
...			
172.16.254.0	172.16.254.1	172.16.254.254	172.16.15.255
172.16.255.0	172.16.255.1	172.16.255.254	172.16.255.255

## With subnetting:

<u>Network</u>	<u>First Host</u>	<u>Last Host</u>	<u>Broadcast</u>	<u>Hosts</u>
172.16.0.0	172.16.0.1	172.16.0.254	172.16.0.255	254
172.16.1.0	172.16.1.1	172.16.1.254	172.16.1.255	254
172.16.2.0	172.16.2.1	172.16.2.254	172.16.2.255	254
172.16.3.0	172.16.3.1	172.16.3.254	172.16.3.255	254
172.16.4.0	172.16.4.1	172.16.4.254	172.16.4.255	254
172.16.5.0	172.16.5.1	172.16.5.254	172.16.5.255	254
172.16.6.0	172.16.6.1	172.16.6.254	172.16.6.255	254
172.16.7.0	172.16.7.1	172.16.7.254	172.16.7.255	254
...				
172.16.254.0	172.16.254.1	172.16.254.254	172.16.15.255	254
172.16.255.0	172.16.255.1	172.16.255.254	172.16.255.255	254
			---	
				65,024

---

$$\begin{aligned}\text{Total address} &= 256 \text{ subnets} * (256 \text{ hosts} - 2) \\ &= 256 * 254 \\ &= 65,024\end{aligned}$$

**NOTE:** It is common for some network administrator to not use the last subnet.

## With subnetting:

<u>Network</u>	<u>First Host</u>	<u>Last Host</u>	<u>Broadcast</u>
172.16.0.0	172.16.0.1	172.16.0.254	172.16.0.255
172.16.255.0	172.16.255.1	172.16.255.254	172.16.255.255

Major Network Address: 172.16.0.0

Major Network Mask: 255.255.0.0

Major Network Broadcast Address: 172.16.255.255

Subnet Mask: 255.255.255.0

---

### First Subnet:

Subnet Address: 172.16.0.0

Subnet Broadcast Address: 172.16.0.255

### Last Subnet:

Subnet Address: 172.16.255.0

Subnet Broadcast Address: 172.16.255.255

# Calculating the number subnets/hosts needed

$2^{10}$	$2^9$	$2^8$	$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
1,024	512	256	128	64	32	16	8	4	2	1
Number of bits borrowed:										
10	9	8	7	6	5	4	3	2	1	
1,024	512	256	128	64	32	16	8	4	2	1
Hosts or Subnets										

172.16.1.0

255.255.255.0

**Network**      **Host**

- Network 172.16.1.0/24
- Need:
  - As many subnets as possible, 60 hosts per subnet

# Calculating the number subnets/hosts needed

$2^{10}$	$2^9$	$2^8$	$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$	
1,024	512	256	128	64	32	16	8	4	2	1	
Number of bits borrowed:					Number of hosts per subnet						
10	9	8	7	6	5	4	3	2	1		
1,024	512	256	128	64	32	16	8	4	2	1	
				Hosts or Subnets							

172.16.1. 0 0 0 0 0 0 0 0

255.255.255. 0 0 0 0 0 0 0 0

← 6 host bits

Host

Network

- Network 172.16.1.0/24
- Need:
  - As many subnets as possible, 60 hosts per subnet

# Calculating the number subnets/hosts needed

$2^{10}$	$2^9$	$2^8$	$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
1,024	512	256	128	64	32	16	8	4	2	1
Number of bits borrowed:										
10	9	8	7	6	5	4	3	2	1	
1,024	512	256	128	64	32	16	8	4	2	1
				Hosts or Subnets				Number of subnets		

172.16.1. 0 0 0 0 0 0 0 0

255.255.255. 1 1 0 0 0 0 0 0 255.255.255.192

← 6 host bits

Network

Host

- Network 172.16.1.0/24
- Need:
  - As many subnets as possible, 60 hosts per subnet
- New Subnet Mask: **255.255.255.192 (/26)**
  - **Number of Hosts per subnet:** 6 bits, 64-2 hosts, **62 hosts**
  - **Number of Subnets:** 2 bits or **4 subnets**



# Calculating the number subnets/hosts needed

$2^{10}$	$2^9$	$2^8$	$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
1,024	512	256	128	64	32	16	8	4	2	1
Number of bits borrowed:										
10	9	8	7	6	5	4	3	2	1	
1,024	512	256	128	64	32	16	8	4	2	1
Hosts or Subnets										

172.16.1.0

255.255.255.0

**Network**      **Host**

- Network 172.16.1.0/24
- Need:
  - As many subnets as possible, 12 hosts per subnet

# Calculating the number subnets/hosts needed

$2^{10}$	$2^9$	$2^8$	$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
1,024	512	256	128	64	32	16	8	4	2	1
Number of bits borrowed:										
10	9	8	7	6	5	4	3	2	1	1
1,024	512	256	128	64	32	16	8	4	2	1
						Number of hosts per subnet				
						Hosts or Subnets				

172.16.1. 0 0 0 0 0 0 0 0

255.255.255. 0 0 0 0 0 0 0 0

← 4 host bits

Network

Host

- Network 172.16.1.0/24
- Need:
  - As many subnets as possible, 12 hosts per subnet

# Calculating the number subnets/hosts needed

$2^{10}$	$2^9$	$2^8$	$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
1,024	512	256	128	64	32	16	8	4	2	1
Number of bits borrowed:										
10	9	8	7	6	5	4	3	2	1	
1,024	512	256	128	64	32	16	8	4	2	1
						Number of hosts per subnet				
						Number of subnets				

172.16.1. 0 0 0 0 0 0 0 0

255.255.255. 1 1 1 1 0 0 0 0 255.255.255.240

← 4 host bits

Network

Host

- Network 172.16.1.0/24
- Need:
  - As many subnets as possible, 12 hosts per subnet
- New Subnet Mask: **255.255.255.240 (/28)**
  - **Number of Hosts per subnet:** 4 bits, 16-2 hosts, **14 hosts**
  - **Number of Subnets:** 4 bits or **16 subnets**

# Calculating the number subnets/hosts needed

$2^{10}$	$2^9$	$2^8$	$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
1,024	512	256	128	64	32	16	8	4	2	1
Number of bits borrowed:										
10	9	8	7	6	5	4	3	2	1	
1,024	512	256	128	64	32	16	8	4	2	1
Hosts or Subnets										

172.16.1.0

255.255.255.0

**Network**      **Host**

- Network 172.16.1.0/24
- Need:
  - Need 6 subnets, as many hosts per subnet as possible

# Calculating the number subnets/hosts needed

$2^{10}$	$2^9$	$2^8$	$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
1,024	512	256	128	64	32	16	8	4	2	1
Number of bits borrowed:										
10	9	8	7	6	5	4	3	2	1	
1,024	512	256	128	64	32	16	8	4	2	1
							Number of subnets			
Hosts or Subnets										

172.16.1. 0 0 0 0 0 0 0 0

255.255.255. 0 0 0 0 0 0 0 0

3 subnet bits →

**Network**

**Host**

- Network 172.16.1.0/24
- Need:
  - Need 6 subnets, as many hosts per subnet as possible

# Calculating the number subnets/hosts needed

$2^{10}$	$2^9$	$2^8$	$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
1,024	512	256	128	64	32	16	8	4	2	1
Number of bits borrowed:			Number of hosts per subnet							
10	9	8	7	6	5	4	3	2	1	
1,024	512	256	128	64	32	16	8	4	2	1
						Hosts or Subnets		Number of subnets		

172.16.1. 0 0 0 0 0 0 0 0

255.255.255. 1 1 1 0 0 0 0 0 255.255.255.224

3 subnet bits →

Network

Host

- Network 172.16.1.0/24
- Need:
  - Need 6 subnets, as many hosts per subnet as possible
- New Subnet Mask: **255.255.255.224 (/27)**
  - **Number of Hosts per subnet:** 5 bits, 32-2 hosts, **30 hosts**
  - **Number of Subnets:** 3 bits or **8 subnets**